SOLAR/2018-78/50

Solar Project Description

REEDY CREEK UTILITIES CO., INC.
OFFICE BUILDING
Walt Disney World
Lake Buena Vista, Florida
July 11, 1978

U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

NOTICE

Solar/2018-78/50
Distribution Category UC-59

SOLAR PROJECT DESCRIPTION
FOR
REEDY CREEK UTILITIES CO., INC. OFFICE BUILDING

Prepared for the
Department of Energy
Office of Assistant Secretary for
Conservation and Solar Applications

Under Contract Number
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In Cooperation with
IBM Corporation, Federal Systems Division
Mueller Associates, Incorporated
The Ehrenkrantz Group

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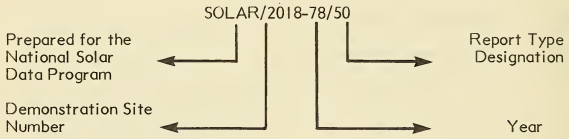
NATIONAL SOLAR DATA PROGRAM REPORTS

Reports prepared for the National Solar Data Program are numbered under a specific format. For example, this report for the Reedy Creek project site is designated as SOLAR/2018-78/50. The elements of this designation are explained in the following illustration:



Demonstration Site Number:

Each project site has its own discrete number - 1000 through 1999 for residential sites and 2000 through 2999 for commercial sites.

Report Type Designation:

This number identifies the type of report, e.g.,

- Monthly Performance Reports -- designated by the numbers 01 (for January) through 12 (for December);
- Solar Energy System Performance Evaluations -- designated by the number 14;
- Solar Project Descriptions -- designated by the number 50;
- Solar Project Cost Reports -- designated by the number 60.

These reports are disseminated through the U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

I. FOREWORD

The National Program for Solar Heating and Cooling is being conducted by the Department of Energy as mandated by the Solar Heating and Cooling Demonstration Act of 1974. The overall goal of the Federal Demonstration Program is to assist in the establishment of a viable solar industry and to achieve a substantial reduction in fossil fuel use through widespread use of solar heating and cooling applications. Analysis and synthesis of the information gathered through this program will be disseminated in site-specific reports and summary documents as products of the National Solar Data Program. These reports will cover such topics as:

- Solar Project Description
- Design/Construction Contractor Final Report
- Project Costs
- Maintenance and Reliability
- Operational Experience
- System Performance Evaluation
- Monthly Performance Reports

The Solar Project Description is prepared for the purpose of documenting the project description in the "as-built" state. Information contained herein has been extracted from data collected during site visits and from reference documents such as the project proposal, designer specifications, contractor submittals, manufacturer's literature, photographs, "as-built" drawings and other project documentation as available. The remaining reports in this series will rely on the Solar Project Description for specific site details.

II. EXECUTIVE SUMMARY

The following is a brief summary of the Reedy Creek Utilities Co., Inc. Office Building solar installation. Highlights of this site include:

- Collector Type - Fixed, horizontal, parabolic trough reflectors with tracking absorbers
- Freeze Protection - Yes-When ambient air temperature reaches 32^{o} F and absorber temperature reaches 35^{o} F, water from the hot storage tank is pumped through the absorbers until the return water temperature reaches 80^{o} F.
- Application - Heating, cooling, hot water
- Storage Type - Exterior hot water, exterior chilled water, above-ground tanks
- New or Retrofit - New
- Performance Evaluation Instrumentation - Yes
- Site-Specific Features - Chilled water storage tank, modular reflectors replacing conventional roofing

The solar energy system heats, cools, and provides domestic hot water for approximately 5,625 square feet of office area in this two-story, modern office building at Walt Disney World, Lake Buena Vista, Florida.

The solar collectors consist of 16 parabolic trough reflectors with tracking absorber tubes and provide an effective aperture area of 3,840 square feet. The reflectors, which are 32 feet long and have a chord width of 7.5 feet, are constructed of aluminum with polyisocyanurate foam insulation. Glass mirror strips are glued to the reflectors with mastic. The reflectors are mounted horizontally on saddles in an east-west direction and replace the conventional roof. Stiffeners were attached to the reflectors to support lights, ducts, and sprinklers. These reflectors were installed using modular construction techniques.

The 34-foot-long absorbers are mounted above the reflectors. Copper absorber tubing is mechanically attached to grooved aluminum absorber plates. These plates are coated with black epoxy paint. The glazing is a single sheet of milky-white selective glass. Polyisocyanurate foam insulates the absorber tubing and a painted aluminum cover protects the absorber assembly. The absorbers are supported at both ends by rocker arms and are interconnected horizontally by

adjustable tie bars. To keep the absorbers in focus, a silicon optical device and motor drive a linear activator that moves the absorbers in a north-south direction. Overheat protection is provided by defocusing the absorbers. There is a freeze protection system. (See page 2.)

Solar energy is transferred from the absorbers to a hot water storage tank by water. The tank, which is 20 feet high and 9 feet in diameter, holds 10,000 gallons, and is located on a concrete slab adjacent to the solar conditioned building. The tank is protected overhead by the reflectors. The tank is insulated with 5 inches of fiberglass insulation that is covered with canvas and insulating cement.

Space heating is provided by circulating hot water from the hot water storage tank to a duct-coil heat exchanger in an air-handling unit. The air-handling unit is located on the roof of a building adjoining the solar conditioned offices. Hot water is provided by circulating city water through a coil in the hot water storage tank. A thermostatic mixing valve mixes cold and hot water so that the temperature of the hot water supply never exceeds 140° F.

Space cooling is provided by chilling water in a 25 ton absorption unit which is operated by hot water from the hot water storage tank. The chilled water is stored in a 10,000-gallon chilled water storage tank which measures 20 feet high and 9 feet in diameter. It is covered with 4 inches of fiberglass insulation, canvas, and insulating cement. Chilled water from this storage tank is piped through a duct-coil heat exchanger in the air-handling unit. The absorption chiller and chilled water storage tank are located outside, next to the hot water storage tank.

The auxiliary energy system provides only chilled water for space cooling requirements. The chilled water is produced by the Central Energy Plant for Walt Disney World which adjoins the solar conditioned building. There is no auxiliary system for space or domestic water heating.

The solar energy system has been fully operational since February 1978. It has been instrumented for performance evaluation and integrated into the National Solar Data Network.

III. SITE AND BUILDING DESCRIPTION

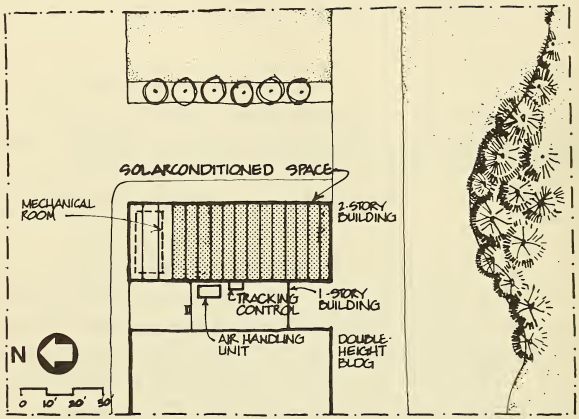


Figure III-1. Site Plan

Site Description

- Special topographic or climatic conditions - Daily afternoon thunderstorms during the summer
- Latitude - 28° N
- Annual degree days (65° F base)
  - Heating - 720
  - Cooling - 3,219
  - Data location - Orlando, Florida
  - Data reference - Local Climatological Data Annual Summaries for 1976, Department of Commerce, National Oceanic and Atmospheric Administration

- Average horizontal insolation
- January - 1,204 Btu/ft^2/day
- July - 1,963 Btu/ft^2/day
- Data location - Tampa, Florida
- Data reference - Solar Heating Design by the F-Chart Method, Beckman, Klein, Duffie, Wiley-Interscience Publication, 1977.
- Site topographic description - Flat
- Shading - None

Building Description

- Occupancy - Office building
- Total area - Approximately 6,400 ft^2
- Solar conditioned area - 5,625 ft^2
- Number of stories - 2
- Roof slope - Flat
- Special features - Entire roof area acts as a collector

Structure

- Walls (Solar conditioned space)
  - o Frame - Concrete block has rebar reinforcement and cores are poured solid.
  - o Exterior finish - Paint
  - o Insulation -
    - Wall exposed to outside -2-in. semirigid insulation (R-8) between 2 1/2-in. metal studs with 1/2-in. gypsum board surface that is attached to interior of concrete block wall
    - Wall adjoining existing building -2-in. semirigid insulation (R-8) between 4 in. metal studs with 1/2-in. gypsum board surface
  - o Interior finish - Paint
  - o Windows - Double-glazed, less than 5% of surface area

- Doors - Solid core

- Roof (Integral part of collector)
  - Structural frame - Sandwich panel collector spans between concrete walls.
  - Exterior finish - Factory and field painted
  - Insulation - 3 in. isocyanurate foam (R-12) located in the collector
  - Interior finish - Factory and field painted
  - Protection for roofing - Not applicable for solar conditioned space because collectors cover entire space. Asphalt roofing strips placed on access roof of adjoining building

- Floor - Reinforced concrete slab on ground floor and ribbed metal deck and concrete on steel joists (4 ft - 0 in. on centers) on second floor

Mechanical System

- Heating
  - Solar - Hot air system
  - Auxiliary - None, due to mild climate. However, during extremely cold weather in the winter of 1977-78, heaters were introduced to heat the building by heating the water in the storage tank. This lasted for 2 days and was considered abnormal. Occupancy of the building was given before the solar system was put into operation.
  - Distribution - Zone system with ducts in ceilings

- Cooling
  - Description - 25-ton chiller operated by water from the storage tank. Chilled water (42° F) is stored in a 10,000 gal cold water storage tank and circulated to an air-handler unit as needed.
  - Distribution - Same as system used for heating
  - Auxiliary - Chilled water supplied by the 19,000 ton/hr central chiller plant

- Domestic hot water
  - Daily water demand - Very small (sinks only)
  - Solar - Water is heated by a coil heat exchanger in the hot water storage tank.
  - Auxiliary - None

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

The Reedy Creek Utilities solar energy commercial demonstration project is represented in figure IV-A-1. The major components of the solar system include 3,800 square feet of modular, parabolic, concentrating collectors, 16 movable absorber tubes with a linear actuator, a 10,000-gallon hot water storage tank, a 25-ton water absorption chiller, a 10,000-gallon chilled water storage tank, and pumps.

Subsequent sections describe the collector, storage, storage-to-load, auxiliary energy, and control subsystems. Figures V-B-1 and V-B-2 show detailed system schematics. Appendices A and B present a glossary and a legend of symbols.

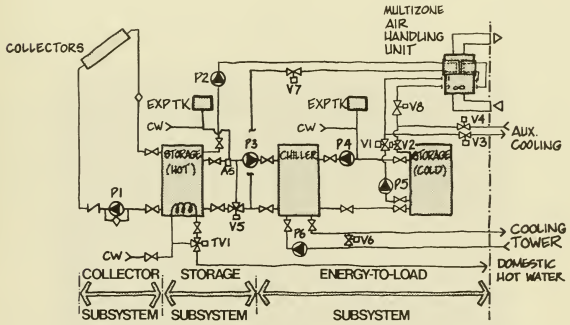


Figure IV-A-1. Overall System Schematic

B. Collector Subsystem

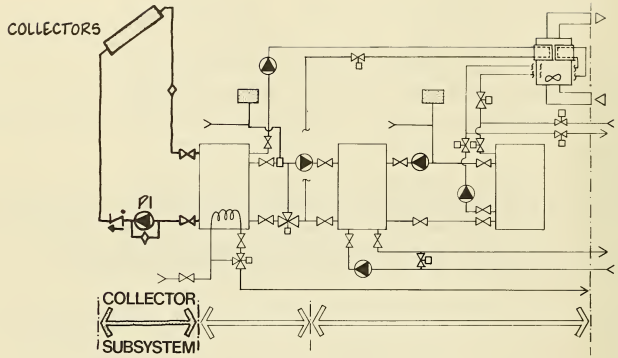


Figure IV-B-1. Collector Subsystem

Sixteen parabolic trough reflectors are mounted on the solar conditioned building. Each reflector is 32 feet long and 8 feet wide (7.5-foot chord length). The 0.06 aluminum top and bottom surfaces are insulated with 3 inches of polyisocyanurate foam and have glass mirror strips glued in place with mastic. Saddles support the reflectors which are placed horizontally in an east-west direction. These reflectors replace the conventional roofing and have stiffeners attached to them so that lights, ducts, and sprinklers can be hung in the offices.

The aluminum absorbers are mounted above the reflectors. There is a slight pitch in the reflectors to allow the rain to drain off. The grooved aluminum absorber plate, painted with black epoxy paint, is mechanically attached to the copper absorber tubing. A single glazing of milky-white selective glass covers the absorber plate. Polyisocyanurate foam insulates the copper absorber tubing.

The absorbers are supported at both ends by rocker arms and are interconnected horizontally by adjustable tie bars. These tie bars are used to keep the absorbers intact. Consequently, the electric-eye sensor and the linear actuator, which drive the absorbers in a north-south direction, can keep the absorbers in focus. The complete collector assembly, including reflectors, saddles, absorbers, and tracking system, were installed as modular units.

Collectors (see figure IV-B-2)

- Type - Tracking and concentrating
- Manufacturer - AAI Corporation, Baltimore, Maryland
- Number - 16
- Collector orientation - Collectors run east - west
- Angle - 0^{o} from horizontal
- Array configuration - 1 row (see figure IV-B-3)

Figure IV-B-2. View of Collectors and the Multizone Air-Handling Unit

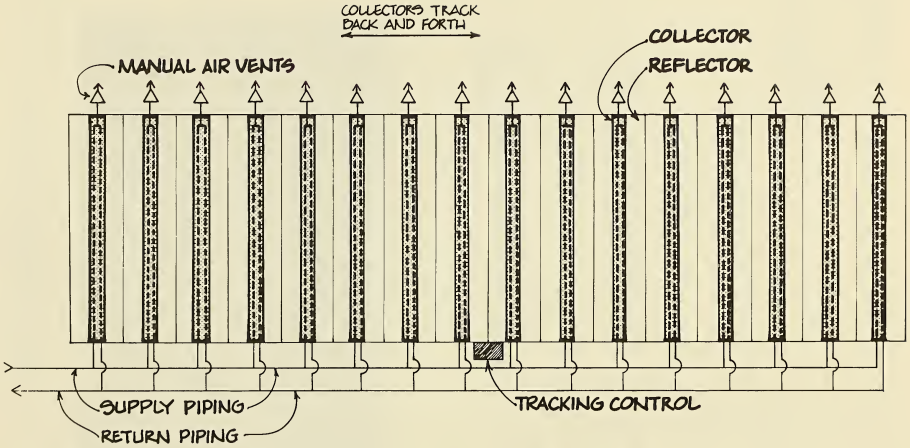


Figure IV-B-3. Solar Collector Array

Description of Collector

- Reflector (Integral with roof) (see figure IV-B-4)
  - General description - Strips of mirrored glass are attached to .060 gage aluminum bowed sandwich panel, shells reinforced with foamed insulation. Reflectors focus light onto absorber plate surface.
  - Total area of reflector surfaces - 3,840 ft^2
  - Total roof area - 3,840 ft^2 (32 ft X 120 ft)
  - Number - 16 curved surfaces
  - Size - Each mirrored glass piece is approximately 2 in. X 63 in. There are six rows of 46 pieces each, per collector.
  - Angle - Varies from 0^o horizontal to approximately 40^o from the horizontal
  - Material - Mirrored glass, manufactured by AAI Corporation, Baltimore, Maryland
  - Adhesive-Mirror Mastic, manufactured by Palmer
  - Support material - .060 aluminum top and bottom bowed panel insulated with 3-in. isocyanurate foam (R-18)
  - Installation - Integral with roof
- Tracking Arm (Absorber) (see figures IV-B-4 and IV-B-5)
  - General Description - The tracking arms are extruded aluminum sections with glazed bottom enclosing absorber-plate copper tubing. Voids are filled with foam insulation. Sixteen absorbers are moved horizontally by a structural metal support mounted above the arms.
  - Glazing
    - Number - Single pane
    - Material - Selective milk-white glass
    - Manufacturer - ASG Industries, Inc.
    - Thickness - 1/8 in.

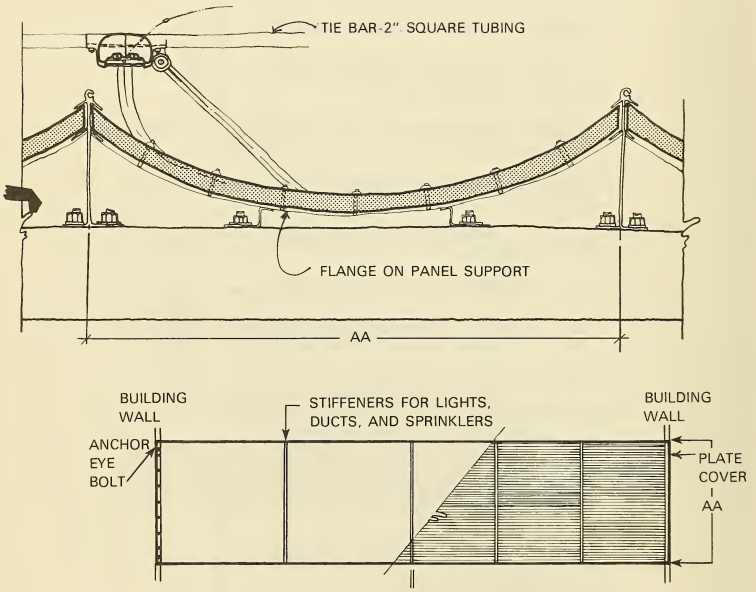


Figure IV-B-4. Side and Top Views of Typical Reflector

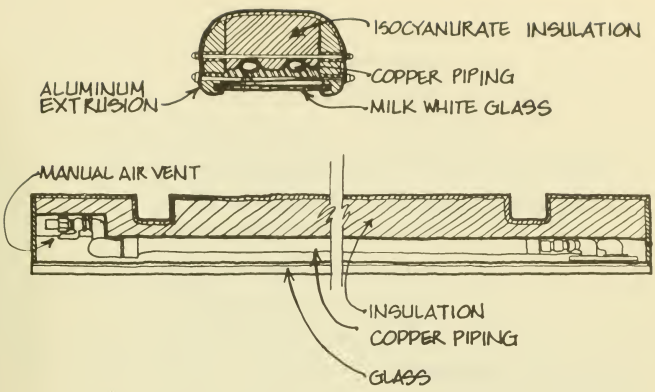


Figure IV-B-5. Sectional Views of the Absorber

Figure IV-B-6. Tracking Arm Assembly for the Drive Motor — Connecting to the Tie-Rods and Absorbers

- Transmittance - 91%
- Reflectance - 9%

o Absorber plate

- Type - Crenolated flat-plate
- Material - Aluminum extrusion
- Thickness - Varies between 1/4 in. and 3/8 in.
- Coating and application - Black paint
- Absorptance - No data available
- Emittance - No data available

o Fluid passage

- Material - Hand-drawn copper tubing
- Bond to absorber - Swaged
- Manifold location - Exterior

o Insulation

- Material - Isocyanurate foam filling tracking arm voids
- R Value - 5 1/2 per in. thickness

Collector Piping (above roof)

- Piping between collector to manifold (see figure IV-B-7)
  - o Material - Glass-fiber reinforced plastic hose
  - o Manufacturer - Aeroquip
  - o Diameter - 1/2 in.
  - o Approximate length per collector - 5 ft
  - o Installation technique - Screw lockwasher at connection to collector. Pipe couplings at connection to manifold. Waterproofing clamped top and bottom. (see figure IV-B-8)
  - o Insulation - 3/4 in. Wall Armaflex, 1-5/8 in. inside diameter over both supply and return pipe, manufactured by Armstrong

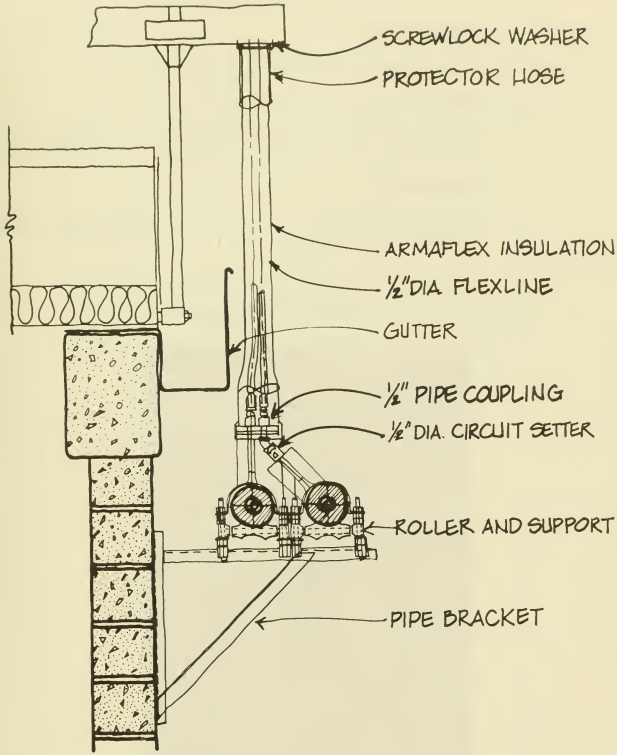


Figure IV-B-7. Piping Between the Collector and Manifold

- Waterproofing - Weather-protector hose (weatherproof plastic on a spiral wire)

- Manifold and branch piping
  - Piping configuration - Direct return
  - Material - Carbon steel
  - Size - Varies from 2 in. to 3 in.
  - Approximate total length - 240 ft
  - Insulation - 1 1/2 in. fiberglass batt (R-6), 3 lb/ft^3 density with vapor carrier and Kraft paper jacket
  - Waterproofing - .016 in. aluminum jacket
  - Supply piping support - Pipe rests on rollers and supports that are held up by a metal angle frame
  - Return piping support - Same as supply-piping support
- Air venting piping - Integral within tracking receiver

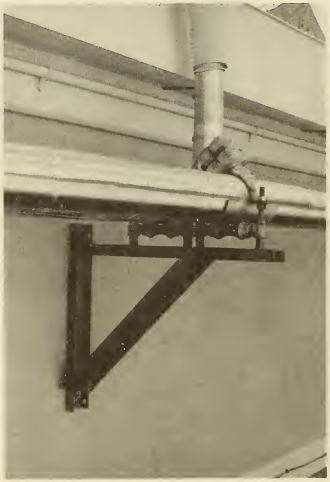


Figure IV-B-8. Piping Connection at Manifold

- Vents
  - o Manual - Simple petcock on each collector. Located in collector (Note: requires use of a cherry-picker for maintenance or adjustment.)
- Valves
  - o Balance - Type - Crane (USA) OS and Y (outside stem and yoke) gate valves and Bell and Gossett "Circuit Setters"
  - o Shutoff - Type - Honeywell spring-loaded automatic control valve, Demco pneumatic valves, and Rockwell plug valves

C. Storage Subsystem

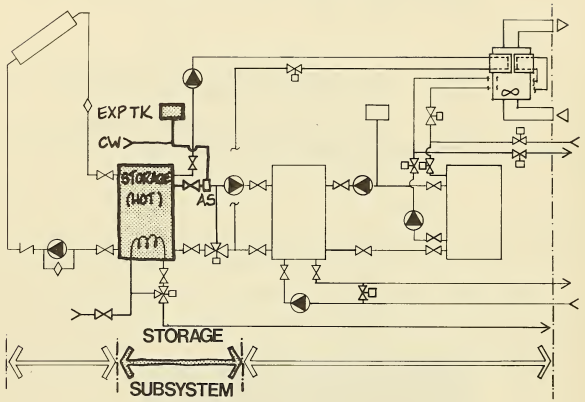


Figure IV-C-1. Storage Subsystem

General Description

Two 10,000-gallon storage tanks are located on a concrete slab next to the main entrance for the solar conditioned offices and are protected overhead by the reflectors. The tanks have a 9-foot diameter and are 20 feet high. The hot water storage tank is covered with 5 inches of fiberglass insulation. The cold water storage tank is covered with 4 inches of fiberglass insulation. Both tanks are protected with canvas and insulating cement.

Tanks (see figures IV-C-2 and IV-C-3)

- o Location - Outside building under roof of main entrance; on concrete grade slab
- o Capacity - 10,000 gal for each tank

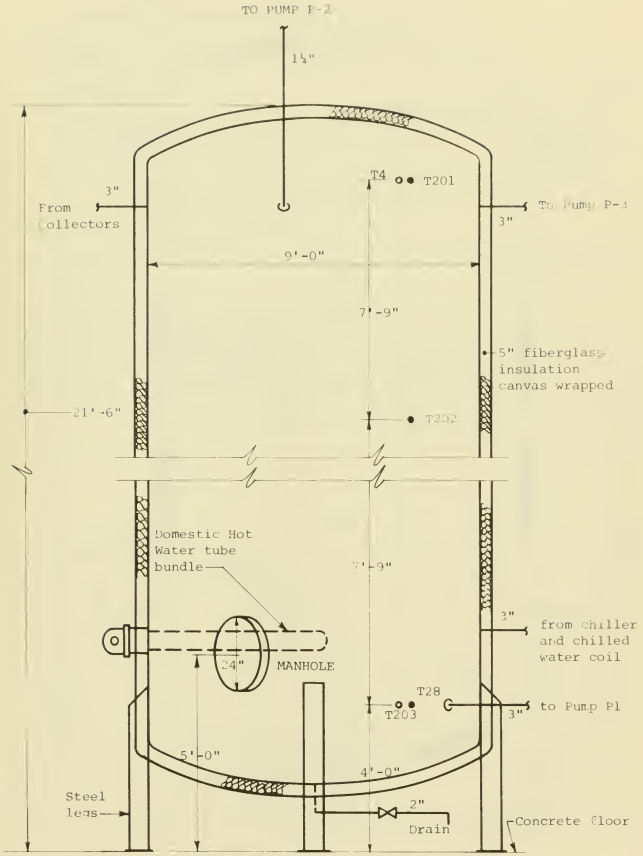


Figure IV-C-2. Hot Water Storage Tank

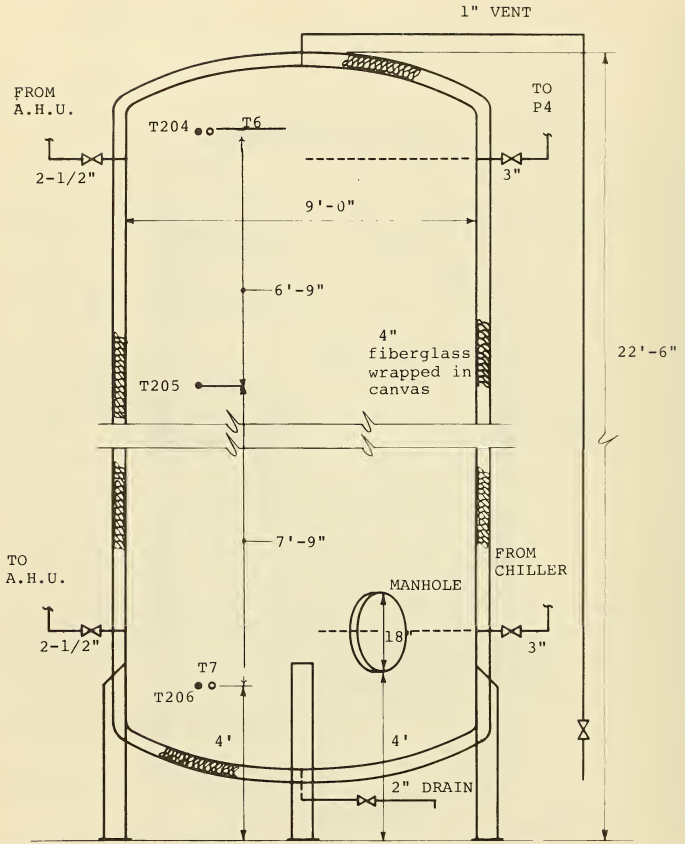


Figure IV-C-3. Cold Water Storage Tank

- Size - 9-ft diameter x 21.5 ft high
- Construction - 1/2 in. steel by Plant City Steel Co.
- Rated working pressure - 125 psi at 625° F
- Insulation
  - Hot water storage tank - 5 in. of fiberglass (R-21) wrapped by canvas and covered with insulating cement
  - Cold water storage tank - 4 in. of fiberglass (R-17) wrapped by canvas and covered with insulating cement
- Waterproofing - Enamel paint
- Installation - Resting vertically with four steel legs on concrete grade floor
- Immersed coils - Domestic water heater
- Piping connections - Threaded pipe tappings welded to tank
- Sensor probe installation - Set in plastic pipe fittings

D. Energy-to-Load Subsystem

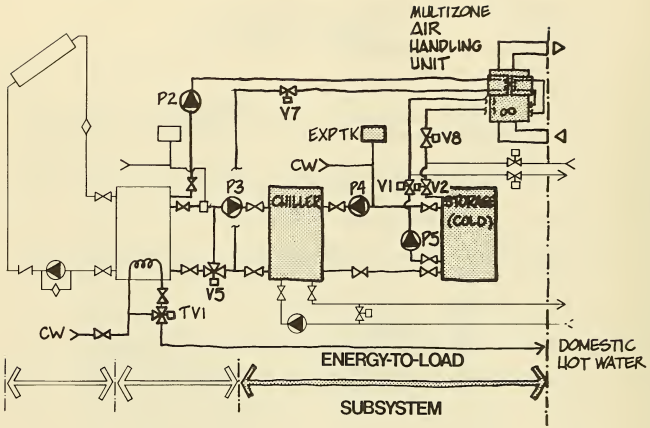


Figure IV-D-1. Energy-to-Load Subsystem

General Description

Domestic hot water is provided by passing city water through a coil heat exchanger in the hot water storage tank. A thermostatic mixing valve mixes cold water with the hot water so that the supply hot water temperature does not exceed 140° F.

Space heating is provided by circulating hot water from the hot water storage tank to a duct-coil heat exchanger in an air-handling unit. Space cooling is supplied by circulating chilled water through a separate coil in the air-handling unit. The two story office building has two zones, one for each floor so that each floor is conditioned separately. The air-handling unit also can exhaust the return air from the building and bring in outdoor air via an energy-efficient enthalpy cycle in the space cooling mode.

The auxiliary energy system only provides space cooling. Chilled water from the Central Energy Plant is piped to the duct coil in the air-handling unit.

1. Space Heating

- General Description - Solar space heating is accomplished by circulating hot water from the hot storage tank through a coil in the Trane multizone air-handling unit. The fan of the Trane unit blows room-return air through the coil and to the spaces. Valve V-7 regulates the amount of hot water flowing through the coil. Pump P-2 is an in-line circulator, mounted in the exposed piping above the roof.
- Piping (interior and exterior) - Steel
- Water-to-air heating coil
  - Manufacturer/Model No. - Trane/Series 15, 1-row
  - Rating - 40,600 Btu/hr
  - Inlet water temperature - 225° F
  - Water flow - 5.6 gal/min
- Automatic Valve (V-7)
  - Type - Pneumatic, two-way modulating
  - Manufacturer - Honeywell
- Pump (P-2)
  - Type - Centrifugal in-line
  - Manufacturer/Model No. - Bell & Gossett/60-115/1 1/4AA
  - Horsepower - 1/3 hp
  - Head - 25 ft

2. Space Cooling

- General Description - Solar space cooling is provided by an Arkla 25 ton, lithium-bromide absorption chiller. Condenser water for the Arkla chiller is provided from the cooling tower system in the Central Energy Plant for the Reedy Creek Utilities Company, Inc. Hot water at temperatures ranging from 160° F to 210° F is circulated between the hot storage tank and the chiller generator by pump P-3. Temperature regulating valve V-5 is set to keep the water supply to the chiller at 180° F for optimum coefficient of

performance. The chilled water is circulated by pump P-4 between the chiller evaporator and a 10,000 gallon cold storage tank. The solar collection system operates 7 days per week and this tank enables chilled water to be stored during weekends and holidays when there is little demand for cooling. Chilled water is circulated between the cold storage tank and a coil in the Trane multizone air handler by pump P-5, and valve V-8 regulates the amount of water flowing through the coil. Pump P-6 circulates tower header and the chiller absorber. Valve V-6 maintains the entering condenser water temperature at 85° F.

- Piping (interior and exterior) - Steel
- Water-to-air cooling coil
  - o Manufacturer/Model No. - Trane/Series 15, 6-row
  - o Rating - 173,200 Btu/hr
  - o Inlet water temperature - 45° F
  - o Water flow - 35 gal/min
- Pump (P-3)
  - o Type - Centrifugal, base mounted
  - o Manufacturer/Model No. - Worthington/D812
  - o Horsepower - 3 hp
  - o Flow rate - 90 gal/min
  - o Head - 70 ft
- Pump (P-4)
  - o Type - Centrifugal, base mounted
  - o Manufacturer/Model No. - Worthington/D812
  - o Horsepower - 1 1/2 hp
  - o Flow rate - 60 gal/min
  - o Head - 40 ft
- Pump (P-5)
  - o Type - Centrifugal, in-line
  - o Manufacturer/Model No. - Worthington/D1130

- Horsepower - 1 hp
- Flow rate - 35 gal/min
- Head - 35 ft

- Pump (P-6)
  - Type - Centrifugal, base mounted
  - Manufacturer/Model No. - Worthington/D812
  - Horsepower - 5 hp
  - Flow rate - 90 gal/min
  - Head - 120 ft
- Automatic Valves (V-1, V-2, V-3, and V-4)
  - Type - Pneumatic, two-way
  - Manufacturer - Demco
- Automatic Valve (V-5)
  - Type - Pneumatic, three-way, modulating
  - Manufacturer - Honeywell
- Automatic Valves (V-6, V-8)
  - Type - Pneumatic, two-way, modulating
  - Manufacturer - Honeywell
- Chiller
  - Type - Absorption, lithium bromide packaged water cooler
  - Manufacturer/Model No. - Arkla
  - Dimensions - 69 in. H x 45 in. D x 114 in. W
  - Weight - 3420 lbs
  - Operating conditions
    - Delivered capacity - 306,000 Btu/hr (25.5 tons)
    - Inlet hot water temperature - 160^{o} to 200^{o} F

- Hot water flow - 90 gal/min
- Hot water Δ P - 20.7 ft
- Heat rejection - 447,000 Btu/hr
- Condensing entering water temperature - 85° to 90° F
- Condensing leaving water temperature - 95° to 100° F
- Condensing water Δ P - 22.9 ft, at 90 gal/min
- Chilled entering water temperature - 55° F
- Chilled leaving water temperature - 45° F
- Chilled water flow rate - 60 gal/min
- Chilled water Δ P - 9.8 ft

- Cooling Tower
  - o Type - Forced draft
  - o Manufacturer - Ceramic Cooling Towers
  - o Capacity - 19,000 tons

3. Auxiliary Cooling

- General Description - Auxiliary cooling is necessary only during long periods of overcast sky when the hot water storage temperature drops below 160° F. Automatic valves V-1 and V-2 close, valves V-3 and V-4 open, and chilled water from the central chilling plant is pumped to the air-handling unit cooling coil.

E. Control Subsystem

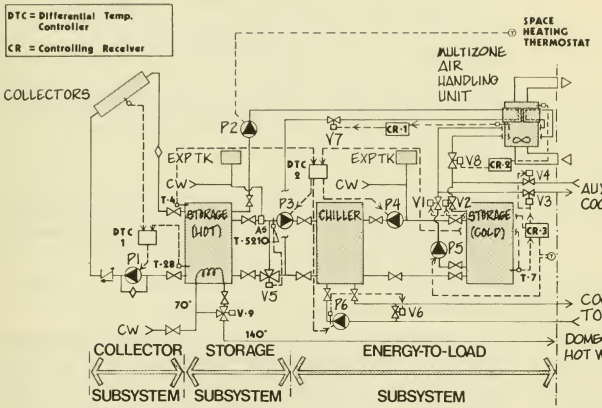


Figure IV-E-1. Control Subsystem

1. Solar Energy Collection Mode

- General Description - The absorber tubes are focused only after silicon optical devices determine that the insolation is greater than a certain threshold level. This threshold level is determined as the minimum light intensity needed so that the solar energy transferred to the heat transfer medium exceeds the electricity used in bringing the absorbers in focus. When the absorber plate temperature is 10° F warmer than the bottom of the hot water storage tank, pump P-1 is activated. After an initial 10-minute interval, the system will remain in the solar energy collection mode until the temperature differential between the water at the collector outlet and the water at the collector inlet is less than 1° F. The overheat protection system starts whenever the sensors on the absorber indicate that the absorber temperature is above 240° F. The absorbers will be driven to their southernmost limit. When the absorber temperature has dropped below 240° F, the absorbers are sent back into a focusing position, after the alarm is shut off with a manual reset.

2. Space Heating Mode

- General Description - Water from the hot water storage tank is circulated through the heating duct-coil in the air handler whenever (1) a differential pressure switch across the air handler indicates that the fan is on; and (2) the temperature in either of the two zones (first floor or second floor) is below 70^{o} F. The fan is programmed to operate daily from 7:00 a.m. to 5:00 p.m., Monday through Friday. The building is occupied daily from 7:00 a.m. to 5:00 p.m., Monday through Friday. Thus, space heating is provided only when the building is occupied. There is no backup heating system.

3. Domestic Water Heating Mode

- General Description - Domestic hot water is heated by passing city water through a coil in the hot water storage tank. A thermostatic mixing valve is placed after the coil to mix cold water with the hot water so that the domestic hot water temperature does not exceed 140^{o} F. There is no backup system.

4. Water Chilling Mode

- General Description - Water from the chilled water storage tank is chilled by an absorption chiller. The chiller is started when the temperature at the bottom of the chilled water storage tank is above 57^{o} F and the temperature of the hot water storage tank is above 180^{o} F. Hot water is passed through the generator in the chiller and chilled water is circulated through the evaporator. Condenser water is piped to the main cooling towers in the Central Energy Plant adjoining the solar conditioned building. The chiller shuts off when either the hot water temperature is below 160^{o} F or the chilled water storage tank temperature is below 45^{o} F.

5. Space Cooling Mode

General Description - Space cooling is supplied by circulating water from the bottom of the chilled water storage tank through the cooling duct coil in the air-handler unit. This mode operates whenever the chilled water storage tank temperature is below 57^{o} F and the room temperature is above 76^{o} F. Furthermore, the differential pressure switch must show that the air-handling fan is on. The auxiliary cooling system is actuated if the room temperature is above 80^{o} F and the chilled water temperature is above 57^{o} F. Chilled water from the Central Energy Plant is passed through the cooling duct coil for 30 minutes and is automatically turned off. This time delay allows the solar system to lower the chilled water temperature to below 57^{o} F. If this does not occur and the room temperature rises above 80^{o} F, the auxiliary cooling system cycles for another 30 minute interval.

V. PERFORMANCE EVALUATION INSTRUMENTATION

A. The National Solar Data Network

The National Solar Data Network (see figure V-A-1) has been developed for the Department of Energy to process data collected from specific commercial demonstration sites which were selected for thermal performance evaluation. The data flow in the Network is shown in figure V-A-2. Products from the Network include monthly and seasonal system-performance reports describing the thermal performance of the solar energy system and subsystems.

The performance evaluation instrumentation at each selected demonstration site is part of a comprehensive data collection system that allows for valid analyses of the solar system performance. Collected data are both applicable and practical in calculating thermal performance factors that describe the behavior of the solar system (see NBSIR 76-1137, National Bureau of Standards). Additional instrumentation may also be included as a result of site-specific requirements. Typically, the instrumentation includes sensors that monitor the following:

- Total insolation in the plane of the collector array
- Ambient temperature
- Collector subsystem flow rate and temperatures
- Storage inlet flow rate and temperatures
- Storage outlet flow rate and temperatures
- Storage temperature
- Storage-to-load subsystem flow rate and temperatures
- Auxiliary fuel flow rates

Site data are recorded automatically at prescribed intervals by the Site Data Acquisition System (SDAS). The recorded data are transmitted daily to the Communications Processor in the Central Data Processing System (CDPS). The communications link between every SDAS and the CDPS consists of voice-grade telephone lines and telephone data couplers. A reading is transmitted from the

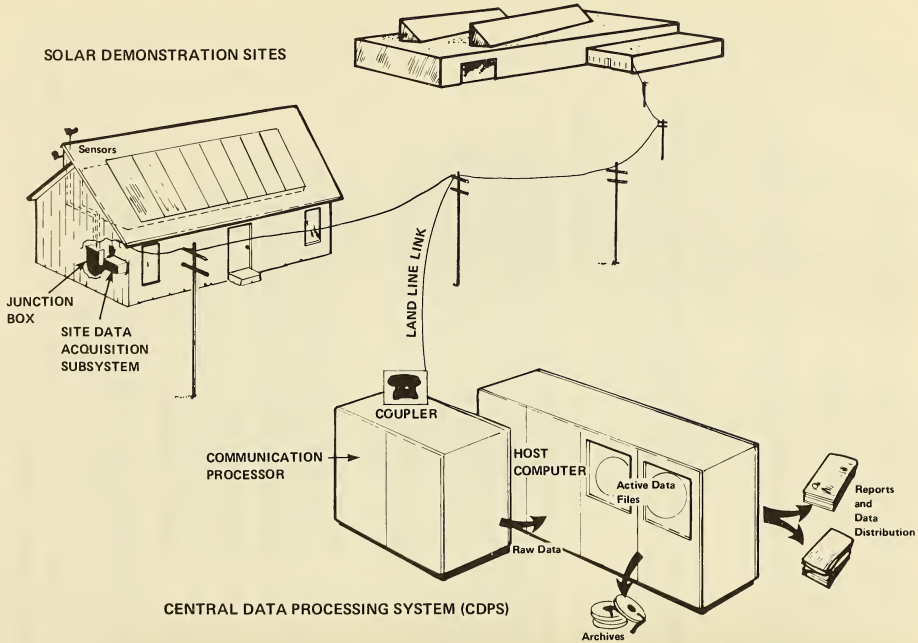


Figure V-A-1. The National Solar Data Network

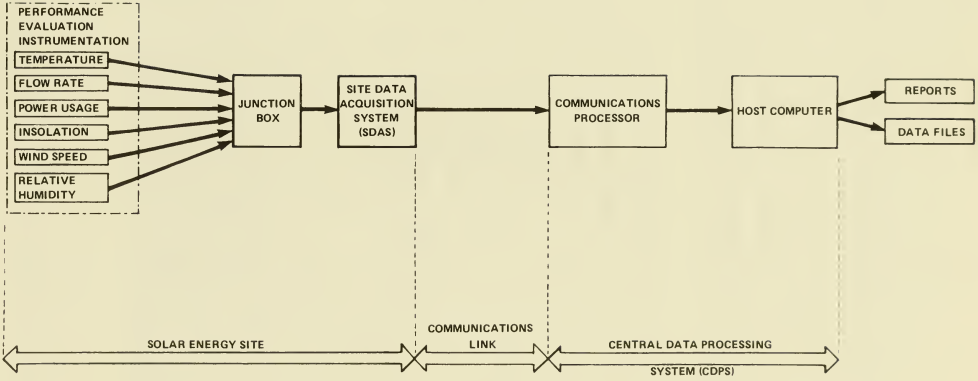


Figure V-A-2. Data Flow Path for the National Solar Data Network

SDAS internal timer with every data sample to ensure that the data are time-tagged correctly.

The Communications Processor scans the receiving data to identify any apparent transmission errors and verifies correct site contact by checking the address code transmitted by the SDAS. Data are stored temporarily in the Communications Processor and processed by the Host Computer. The processing includes measurement checking to ensure that the data are reasonable; that is, that they are not beyond the known instrument limits and they they are not erratic. Data which appear questionable are discarded and are not used in the solar system performance analyses.

Appropriate equations were formulated and programmed to define desired performance factors for the solar energy systems at each selected demonstration site. A performance factor is a number that describes either the efficiency or the quantity of energy lost, gained, or converted by a solar energy system or by a component. All valid data are processed using these performance factor equations to generate hourly performance factors. Hourly performance factors are integrated into daily and monthly performance factors. These hourly, daily, and monthly performance factors are stored in data files in the CDPS. These data files also include measurement data, expressed in engineering units; numerical and textual site identification; and specific site data used in generating the performance factors.

B. Onsite Instrumentation

The onsite instrumentation includes sensors to monitor the various parameters of the solar energy system, a junction box, and a Site Data Acquisition System that stores and transmits data to the Host Computer (see figure V-A-1 and V-A-2). Specific information for temperature, flow, power, and miscellaneous sensors is presented in tables V-B-1 through V-B-4, respectively. Sensor locations are shown in figures V-B-1 and V-B-2.

Table V-B-1. Temperature Instrumentation for Reedy Creek Utilities Co., Inc.

SENSOR	NAME	RANGE (F)		MFGR.	THERMOWELL PART NO.
		Min.	Max.		
T001	Outdoor Ambient Temperature	-20	120	Minco	
T100	Collector Inlet Temperature	30	450	"	F203U15
T150	Collector Array Outlet Temperature	30	450	"	F203U15
T102	Collector Surface Temperature	30	450		(RTV Adhesive) (DC732)
T201	Hot Storage Tank Top Temperature	30	450	"	F203U154
T202	Hot Storage Tank Middle Temperature	30	450	"	F203U154
T203	Hot Storage Tank Bottom Temperature	30	450	"	F203U154
T204	Cold Storage Tank Top Temperature	-20	120	"	F203U154
T205	Cold Storage Tank Middle Temperature	-20	120	"	F203U154
T206	Cold Storage Tank Bottom Temperature	-20	120	"	F203U154
T350	Domestic Hot Water Heat Exchanger Outlet Temperature	30	230	"	F203U10
T302	Domestic Hot Water Supply Temperature	30	230	"	F203U10
T402	Hot Load Supply Inlet Temperature	30	230	"	F203U10
T452	Hot Load Supply Outlet Temperature	30	230	"	F203U10
T501	Arkla Condenser Water Inlet Temperature	30	160	"	F203U15
T551	Arkla Condenser Water Outlet Temperature	30	160	"	F203U15
T502	Arkla Generator Water Inlet Temperature	30	230	"	F203U10
T552	Arkla Generator Water Outlet Temperature	30	160	"	F203U10
T503	Arkla Chilled Water Outlet Temperature	30	160	"	F203U15
T553	Arkla Chilled Water Inlet Temperature	30	230	"	F203U15
T504	Chilled Water Supply Inlet Temperature	-20	120	"	F203U10
T554	Chilled Water Coil Outlet Temperature	-20	120	"	F203U10
T555	Chilled Water Tank Inlet Temperature	-20	120	"	F203U15
T600	Return Air Temperature	30	160	"	F132
T300	Domestic Hot Water Heat Exchanger Inlet Temperature	30	160	"	F203U10
T505	Chilled Water Tank Outlet Temperature	-20	120	"	F203U15

Table V-B-2. Flow Rate Instrumentation for Reedy Creek Utilities Co., Inc.

SENSOR	NAME	RANGE (GPM/CFM)			MFGR.	MODEL NO.
		Min.	Design	Max.		
W100	Collector Array Flow Rate	0		197.1	Ramapo	MK-V-3-W01
W300	Domestic Hot Water Solar Flow Rate	0		9.90	"	MK-V-1-J01
W301	Domestic Hot Water Supply Flow Rate	0		9.83	"	MK-V-1-J07
W401	Hot Water Coil Supply Flow Rate	0		9.82	"	MK-V-1-¼/v-J01
W501	Arkla Condensing Water Flow Rate	0		149.26	"	MK-V-3-W01
W502	Arkla Hot Water Flow Rate	0		120.3	"	MK-V-2-1/2-W01
W503	Arkla Evaporator Water Flow Rate	0		195.26	"	MK-V-3-W01
W504	Chilled Water Supply Flow Rate	0		98.0	"	MK-V-2-1/2-W01

Table V-B-3. Power Instrumentation for Reedy Creek Utilities Co., Inc.

SENSOR	NAME	PHASE	MFGR.	FULL SCALE INPUT		MODEL NO.
				Volts	Amps	
EP101	Collector Pump Power	3	Ohio Semitronics	480	5.0	PC5-6
EP102	Tracker Motor Power	3	"	480	5.0	PC5-6
EP401	Hot Water Supply Pump Power	3	"	480	5.0	PC5-6
EP402	Internal Air Recirculating Fan Power	3	"	480	10.0	PC5-15
EP403	Hot Water Coil Supply Pump Power	1	"	120	5.0	PC5-1
EP501	Arkla Chiller Operating Power	1	"	120	5.0	PC5-1
EP502	Arkla Chilled Water Pump Power	3	"	480	5.0	PC5-6
EP503	Condenser Water Pump Power	3	"	480	10.0	PC5-15
EP504	Chilled Water Coil Pump Power	3	"	480	5.0	PC5-6

Table V-B-1. Miscellaneous Instrumentation for Reedy Creek Utilities Co., Inc.

SENSOR	NAME	MODEL NO	MFGR.
I001	Collector Plane Total Insolation	PSP	Eppley
I002	Collector Plane Diffuse Insolation	PSP with Shadow Ban	Eppley

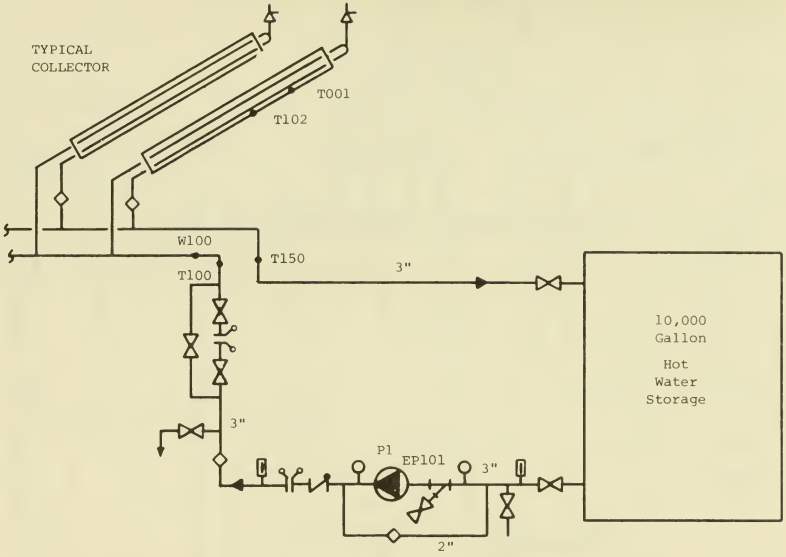


Figure V-B-1. Collector Subsystem

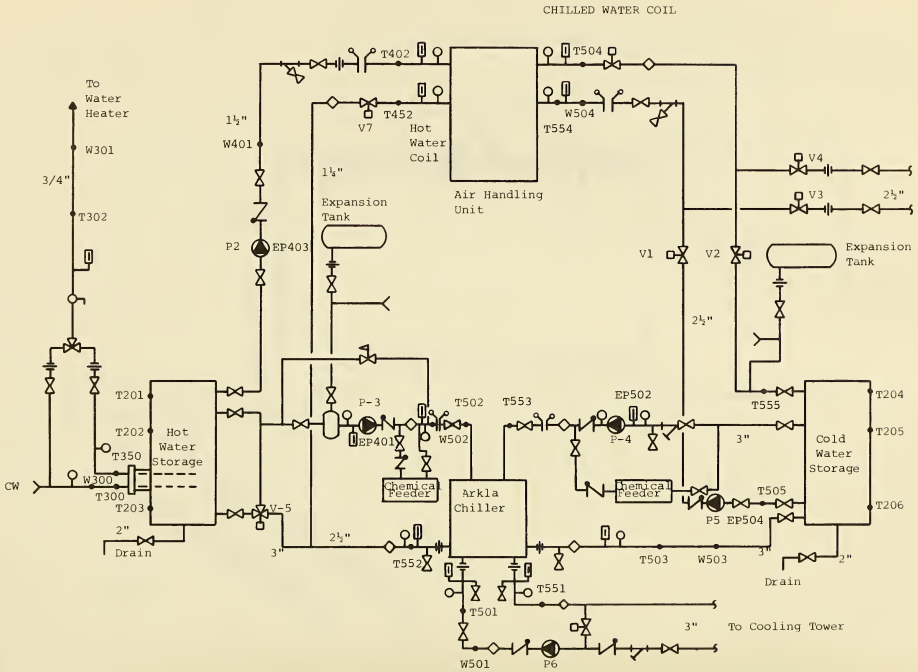


Figure V-B-2. Storage-to-Load Subsystem

IV. APPENDIX

A. Glossary

ABSORBER PLATE - The surface in a flat-plate collector that absorbs incident solar radiation and transfers the absorbed energy to a heat transfer fluid.

ABSORPTANCE - The ratio of absorbed radiation by a surface to the total incident radiation on that surface.

ABSORPTION SUBSYSTEM - The mechanical equipment that conditions indoor air by an absorption process.

ACTIVE SOLAR SYSTEM - An integrated solar energy system, consisting of collector, storage, solar energy-to-load subsystems, that can condition indoor air or preheat domestic hot water in a controlled manner.

AIR-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which air is the heat transfer fluid.

AIR CONDITIONING - The process of treating indoor air by controlling the temperature, humidity, and distribution to specified comfort settings as set by the occupants in the conditioned space.

AMBIENT AIR - A term for outdoor air, which may be brought into a building to be conditioned or circulated.

ANTIFREEZE FREEZE PROTECTION SYSTEM - A freeze protection system that uses a solution of water and glycol. This solution depresses its freezing point sufficiently to prevent possible water freeze in solar collectors and exterior piping.

AUXILIARY ENERGY SUBSYSTEM - The equipment which uses conventional energy sources to supplement the output provided by a solar energy system and to provide a full backup system when the solar system is inoperable.

BACKFLOW - The unintentional reversal of flow in a potable water distribution system by foreign or toxic substances that may contaminate the potable water.

BACKFLOW PREVENTER - A device or means to stop backflow.

BEAM RADIATION - Solar radiation which is not scattered and may be concentrated.

BRITISH THERMAL UNIT (Btu) - A unit of energy that is required to heat one pound of water from 59^{o} F to 60^{o} F.

BUILDING ENVELOPE - The exterior surface of a building that encloses the conditioned space.

CLIMATE - The prevailing or average weather conditions of a specific geographic region as described by temperature and other meteorological data.

COLLECTOR MANIFOLD - The piping that connects the absorber tubes in a collector plate.

COLLECTOR PLATE - A term used for an absorber plate.

COLLECTOR SUBSYSTEM - The assembly that absorbs incident solar radiation and transfers the absorbed thermal energy to a heat transfer fluid.

COMBINED COLLECTORS - An assembly that both collects incident solar radiation and stores the thermal energy in the same unit.

CONCENTRATING SOLAR COLLECTOR - A solar collector which focuses beam radiation onto an absorber to obtain higher energy fluxes than can normally be achieved by flat-plate solar collectors.

CONCENTRATOR - A reflective surface or refracting lens used in directing insolation onto an absorber.

CONDITIONED SPACE - The space in a building that has the air conditioned for heating and cooling.

CONTROL SUBSYSTEM - The assembly of electric, pneumatic, and hydraulic actuated sensing devices used in regulating the solar energy system and the auxiliary energy subsystem.

COOLING TOWER - A heat exchanger that transfers waste heat from an absorption cooling system to ambient air.

DIFFUSE RADIATION - Solar radiation which is scattered by air molecules, dust, or water droplets and cannot be focused.

DRAIN-DOWN FREEZE PROTECTION SYSTEM - A freeze protection system that prevents potential water freeze problems by automatically opening a valve to drain the solar collectors and exterior piping. Air is used for some systems, nitrogen for others.

DUCT HEATING COIL - A liquid-to-air heat exchanger in the duct distribution system used to heat air by passing a hot fluid into a coil in the airstream.

EMITTANCE - The ratio of energy radiated by a body to the energy radiated by a blackbody at the same temperature.

EQUIVALENT FULL LOAD COOLING HOURS - The seasonal cooling load for a building described as the total number of hours that the air conditioning system will operate under full load conditions to meet the required cooling load.

EXPANSION TANK - A tank which will permit water to expand whenever it is heated to prevent excessive pressures on the other system components.

FIXED COLLECTOR - A solar collector permanently oriented toward the sun which cannot track the sun nor be adjusted for seasonal variations.

FLAT-PLATE COLLECTOR - A basic heat collection device used in solar heating systems, which consists of an absorber plate, with insulated bottom and sides, and is covered by one or more transparent covers. There are no concentrators or focusing aids in a flat-plate collector.

FOCUSING COLLECTOR - A solar collector which uses a parabolic mirror, Fresnel lens or other type of focusing device to concentrate solar radiation onto an absorber.

FRESNEL COLLECTOR - A concentrating solar collector which uses a Fresnel lens to focus beam radiation onto an absorber.

GLAZING - The transparent cover(s) on a solar collector used to reduce the energy losses from the top of the collector.

HEAT TRANSFER FLUID - The fluid that transfers solar energy from the solar collector to the storage subsystem or to the load.

INCIDENCE ANGLE - The angle at which the insolation strikes a surface and the normal for that surface.

INSOLATION - The total amount of solar radiation on a surface in a given unit of time.

LAMINATED GLASS - A glazing consisting of multiple glass sheets bonded together by intervening layer or layers of plastic.

LANGLEY - The standard unit of insolation defined as 1 langley = 1 cal/cm^2 (1 langley = 3.69 Btu/ft^2).

LIQUID-BASED SOLAR COLLECTOR SYSTEM - A solar energy system in which either water or an antifreeze solution is the heat transfer fluid.

LOAD - The total space conditioning or domestic water heating requirements that are supplied by both the solar energy system and the auxiliary energy subsystem.

NOCTURNAL RADIATION - The loss of thermal energy by the solar collectors to the sky at night.

NO-FLOW CONDITION - The condition obtained when the heat transfer fluid is not flowing through the collector array due to shutdown or malfunction.

OPAQUE - A surface that is not transparent, thus solar radiation is either reflected or absorbed.

OUTGASSING - The emission of gases by materials and components, usually during exposure to elevated temperature or reduced pressure.

PACKAGE AIR-CONDITIONING UNIT - A factory-made assembly consisting of an indoor coil, a compressor, an outdoor coil, and other components needed for space cooling operations. Unit may also include additional components to heat the conditioned space.

PARABOLIC FOCUSING COLLECTOR - A concentrating collector which focuses beam radiation by a parabolic reflector.

PASSIVE SOLAR SYSTEM - An integrated solar energy system that can provide for space heating needs without use of an energy source other than the sun.

PEBBLE BED - A storage tank using uniform-sized pebbles to store solar energy in air-based solar collector systems.

REFLECTANCE - The ratio of radiation reflected by a surface to the total incident radiation on the surface.

REFLECTED RADIATION - Insolation which is reflected from a surface, such as the ground, and is incident on the solar collector.

SELECTIVE SURFACE - A surface which has a high absorptance for solar radiation and a low emittance for thermal radiation.

SOLAR CONDITIONED SPACE - The area in a building that depends on solar energy to provide a fraction of its heating and cooling needs.

SOLAR HEATING SYSTEM - An integrated assembly of collector, storage, solar energy-to-load, and control subsystems required to convert solar energy into thermal energy for space heating requirements--also includes an auxiliary backup system.

SOLAR RETROFIT - The addition of a solar energy system to an existing structure.

STORAGE SUBSYSTEM - The components used to store solar energy for use in heating or cooling air, or heating water during period of low insolation.

STRATIFICATION - The horizontal layering by a fluid due to temperature differentials, commonly noticed in storage tanks filled with water.

THERMOSTAT - A temperature dependent sensor which controls either the heating and cooling systems for space conditioning or the hot water heater.

TON OF REFRIGERATION - A unit of refrigeration equivalent to 12,000 Btu/hr.

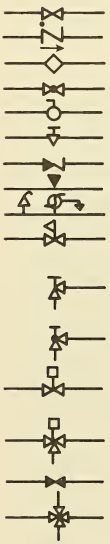
TRACKING COLLECTOR - A solar energy collector that constantly moves to follow the path of the sun.

VAPOR BARRIER - A material which is used to reduce the transmission of water vapor.

ZONE - Portions of a conditioned space which use a common control because of their similar heating and cooling requirements.

B. Legend for Solar System Schematics

VALVES



FITTINGS

PIPING SPECIALITIES

AS	AIR SEPARATOR
EXP TK	EXPANSION TANK
WS	WATER SOFTENER
HED	HOSE END DRAIN